How Radar is Displacing Traditional Technologies

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Introduction

As the level of autonomy in cars increases, choosing the right number and type of sensors becomes more complex. Traditional sensing options are available, but over the years, the application of radar within the automotive industry has positively evolved the definition of safety and efficiency.

Because it can work in extreme environmental conditions such as rain, snow, dust and bright sunlight and also provide precise distance and velocity information, radar is considered the most appropriate sensing modality to meet New Car Assessment Program (NCAP) requirements. Vehicle architectures are increasingly relying on smart radar sensors, with all processing occurring at the edge to send object lists to central electronic control units.

Radar sensing has become a cost-efficient sensing modality for required advanced driver assistance system (ADAS) functions and to meet Society for Automotive Engineers vehicle autonomy levels 2+ and even 3+, as shown in **Figure 1**. Radar technology is evolving to support higher levels of automated driving, with high levels of range and resolution for precise detection and decision. And because radar sensors can now support multiple functions, the use of space around the vehicle becomes more manageable. As the numbers of sensors increase, the space around the car becomes constrained. Due to multimodal functionally of the sensors, engineers are eventually able reduce the number of sensors.

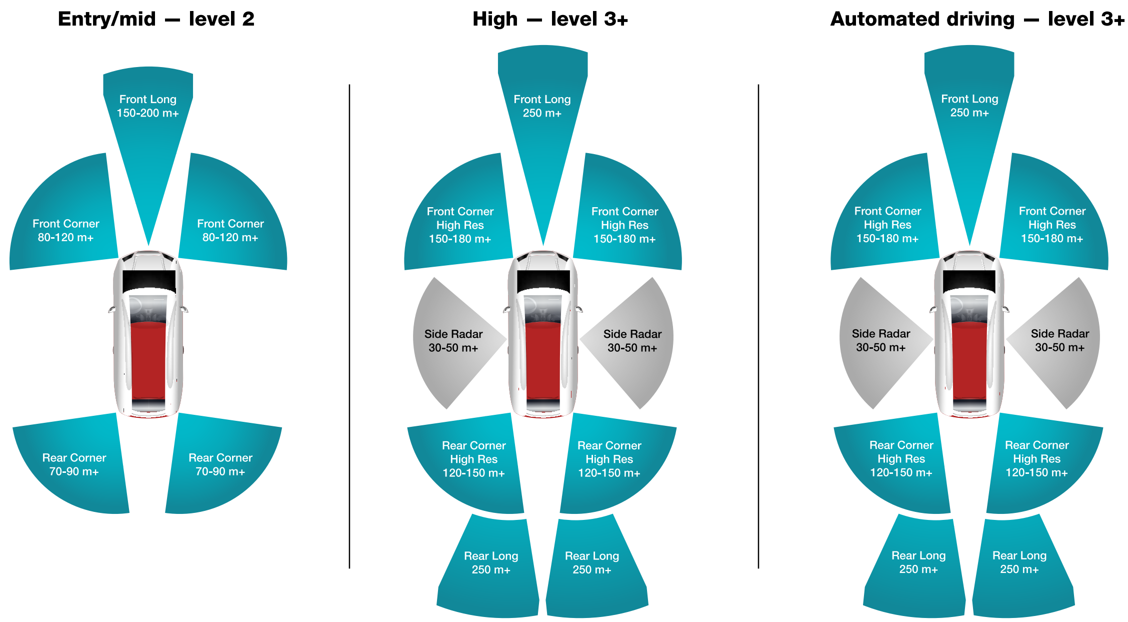

Figure 1. *Radar sensors enable advanced levels of autonomy.*

Up to level 3+, vision and radar sensing modalities can cost efficiently address the requirements, while for level 4 and beyond, all three sensing modalities – including lidar – might be necessary (as shown in **Table 1**). Radar sensors, when built with cascaded transceivers (a higher number of virtual channels), offer lidar-like performance (higher angular resolution), but at an optimized cost.

Level 2+ 5 sensors	Front: 1 short range 1 medium range
	Rear: 1 short range 1 medium range 1 long range
Level 3+ 7 or more sensors	All of the sensors named above for front and rear Plus sensors on each side of the car for 360° coverage
Level 4 and beyond All sensing modalities	Front: Short- and medium-range sensors Rear: Short-, medium- and long-range sensors Sides: May include all sensing modalities including cameras, radar and lidar

Table 1. *Autonomy levels and their corresponding sensing requirements.*

Radar technology alerts drivers to the possibility of a collision by providing a warning or taking necessary evasive action. The complexity of safely turning or changing lanes and navigating tight corners presents significant design challenges when working to advance vehicle autonomy, however. Visibility around corners has presented major technical barriers in designing high-quality ADAS and parking assistance, as well as affecting the broader adoption of autonomous vehicles worldwide. Being able to see farther and more clearly with radar devices leads to improved sensor fusion for safer automated driving and parking applications. In addition to the performance that radar brings to the table, the key advantage of using radar for ADAS is its ability to operate reliably regardless of weather conditions.

77- to 81-GHz millimeter-wave (mmWave) long-range radar sensors from TI offer the ability to detect objects in a wide geographical area and can cover a range of 200 m. Mid-range sensors operate in the range of 100 m to 150 m, while short-range sensors use transceivers, with signal-processing equipment mounted behind the bumper, to track an object or person 30 m to 50 m from the vehicle. Complementary metal-oxide-semiconductor technology has enabled a high level of integration in our front end, especially a single chip that integrates both analog and digital.

Advancing from 24-GHz to 77-GHz radar for mid- and short-range applications

For short-range radar, the 24-GHz narrow and ultrawide bands have been used in legacy automotive sensors. For simple applications such as basic blind-spot detection, you can use the industrial, scientific and medical (ISM) band, but in most cases, including ultra-short-range radar applications, the need for high-range resolution dictates use of the ultrawide band. This 24-GHz ultra-wide band will be phased out soon, however, given spectrum regulations and standards developed by the European Telecommunications Standards Institute and the U.S. Federal Communications Commission. The 24-GHz ultra-wide band became unavailable as of January 1, 2022, known as the "sunset date," in both Europe and the U.S.; only the narrow ISM band will be available in the long term. The lack of wide bandwidth in the 24-GHz band, coupled with the need for higher performance in emerging radar applications, makes 24 GHz unattractive for new short-range radar implementations.

There is a 76- to 77-GHz band available for vehicular long- and mid-range radar applications. This band has the benefit of high allowed equivalent isotropic radiated power, which enables front long-range radar applications such as adaptive cruise control. The 77- to 81-GHz short-range radar band has recently gained significant traction, both from a worldwide regulation perspective as well as industry adoption.

One of the key benefits of 77 GHz frequency band for automotive is its wide bandwidth. Compared to the 200-MHz ISM band, which is available at 24 GHz, the 77- to 81-GHz short-range radar band offers up to 4 GHz of sweep bandwidth, significantly improving range resolution and accuracy. The range resolution of a radar sensor signifies its ability to separate two closely spaced objects, whereas the range accuracy represents the accuracy in measuring the distance of a single object. Since range resolution and accuracy are inversely proportional to the sweep bandwidth, a 77-GHz radar sensor can achieve 20 times better performance in range resolution and accuracy compared to 24-GHz radar. The achievable range resolution is 4 cm (versus 75 cm for 24-GHz radar) as shown in **Figure 2**. Because the 24-GHz band will be restricted to narrow bandwidth, moving forward, most 24-GHz automotive radar sensors will likely shift to the 77-GHz band.

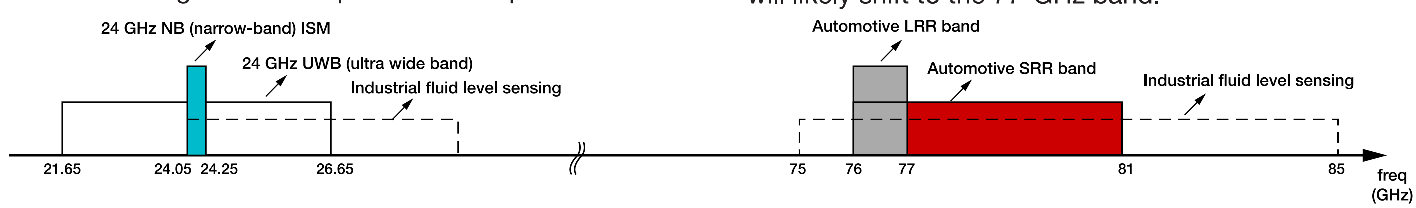

Figure 2. *77-GHz Wide bandwidth with provides higher range resolution and accuracy.*

Smaller sensor size is another advantage of a higher radio frequency. For a chosen antenna field of view and gain, the size of the antenna array can be approximately three times smaller each in the X and Y dimensions when comparing 77 GHz to 24 GHz (see **Figure 3**).

This size reduction is particularly useful in the context of automotive applications (where sensors need to be mounted in tight spots behind the bumper); in other spots around the car, including doors and trunks for some proximity applications; and inside the car for in-cabin applications.

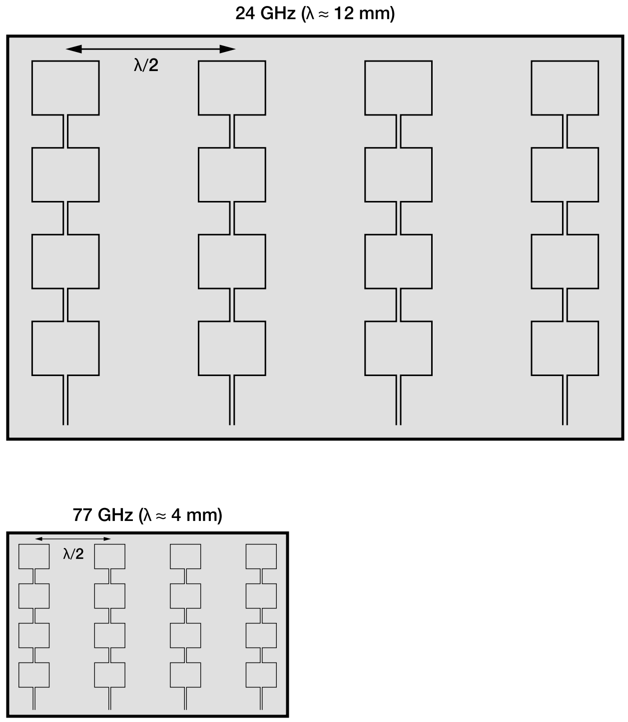

Figure 3. *The 77-GHz antenna array is significantly smaller than the 24-GHz antenna array.*

Imaging radar vs. lidar

In current driver assistance systems, primary safety measures such as automatic emergency breaking (AEB), autonomous emergency steering (AES), automatic cruise control (ACC) and forward collision warning (FCW) are considered basic features and mandated per regional NCAP regulations. As development in ADAS continue, car safety ratings are including more and more ADAS and crash avoidance technologies. The performance of safety measures such as AEB, AES, ACC and FCW depends on the type and complexity of sensors used. Original equipment manufacturers (OEMs) and Tier-1 suppliers are paying very close attention to the sensor suite they choose for these functions, specifically ensuring that radar sensors meet the stringent requirements that NCAP tests require. Traditionally, pedestrian avoidance, lane-change warnings, auto-braking solutions and adaptive cruise control applications use lidar.

Automotive lidar sensors use light as a transmission source. The integration of lidar sensors enables the detection of objects nearly 200 m in front of the vehicle. High cost is a primary concern when using lidar, however. Recalling **Table 1**, vision and radar sensing modalities can cost-efficiently address requirements to autonomy level 3+, while level 4 and beyond may require all three sensing modalities.

A sensor configuration in which multiple TI **AWR2243** mmWave sensors are cascaded together enables imaging radar by operating synchronously as one unit, with many receive and transmit channels to significantly enhance the angular resolution as well as the radar range performance. When cascaded together, mmWave sensors can reach an extended range of up to 400 m using integrated phase shifters to create beamforming.

A common use case that highlights the advantages of imaging radar sensors is their ability to identify static objects in high resolution as shown in **Figure 4**. The typical mmWave sensor has high velocity and range resolution, which enables it to easily identify and differentiate between moving objects, but it is quite limited when it comes to static objects.

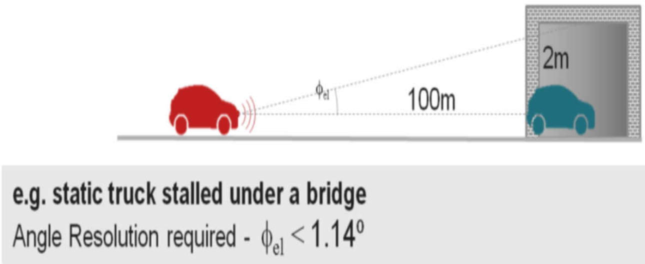

Figure 4. *An imaging radar's ability to differentiate and identify static objects.*

Expanding radar to new applications

With more sensors required to achieve a 360-degree surround view, auto manufacturers need to integrate sensors in small spaces such as door handles or B-pillars for better coverage. The small form factor of TI's **AWR1843AOP** and **AWR6843AOP** antenna-on-package (AOP) sensor enables sensor integration into new places. As automakers and Tier-1 suppliers turn to radar mmWave sensors for improved performance when detecting objects in emerging applications, TI's AoP mmWave radar sensor integrates the antenna, radar transceiver, digital signal processor, microcontroller and interface peripherals all onto one chip. Integrating the package onto the chip eliminates the need for a high-frequency substrate material, greatly reducing costs as well as manufacturing complexity when compared to other radar sensors while saving about 30% of board space. Eliminating the need to design, simulate and characterize antenna performance can even speed time to market. TI's software is also reusable and portable across the company's 60- and 77-GHz devices, enabling faster multiradar system-level designs.

Radar for ultra-short-range applications

Today, surround-view cameras and ultrasonic sensors enable parking assistance. Drivers are still required to make judgments and maneuver based on sensor feedback, however. Plus, in severe weather conditions these sensing modalities cannot work independently; thus, the cars are not completely autonomous.

To enable automated parking functionality, the sensor should be capable of detecting other cars, curbs or pedestrians from 3 cm to more than 40 m away in a wide field of view, in any kind of environmental conditions. mmWave sensors help achieve this functionality by accurately detecting smaller objects (such as a metal rod protruding from the ground) that other sensing modalities may not be able to detect from a distance less than 25 cm, all while functioning under a variety of weather and lighting conditions. Radar sensors also improve the overall aesthetics of vehicles because they operate behind the bumper and do not require any drilling of holes on bumpers.

The AWR1843AOP provides a wide field of view in both azimuth and elevation that enables true 3D detection for various objects. A wide field-of-view with the integrated antenna makes it possible to achieve 360° coverage with a minimal number of sensors, as shown in **Figure 5**.

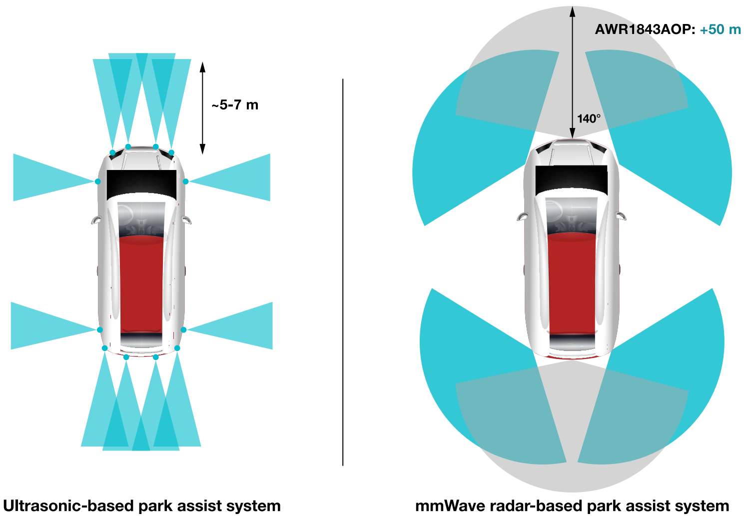

Figure 5. *Comparison of range and field of view for ultrasonic vs. mmWave radar systems.*

A mmWave radar sensor's 77-GHz bandwidth enables high range resolution so that it can distinguish between various types of objects across a wide field of view, including wood, metal and plastic, as shown in **Figure 6**.

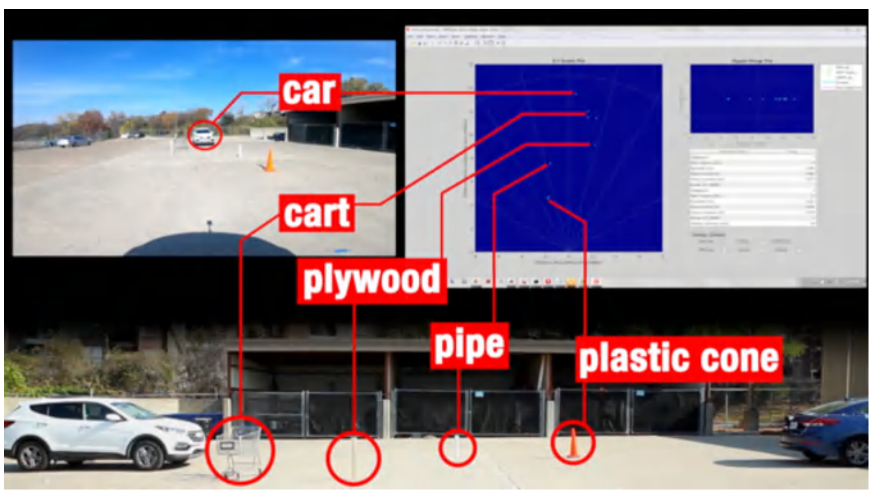

Figure 6. *Multiple types of objects detected by a mmWave radar sensor.*

Driver monitoring for ADAS

Radar sensors are not only changing the way that vehicles sense the environment around them, but also how radar senses what is inside them.

The capabilities of radar sensor such as **AWR6843AOP** for in-cabin sensing continue to grow, increasing the accuracy of systems such as driver monitoring systems, seat-belt reminders and airbag deployment, better serving the vehicle's occupants. Heavy objects laid on a seat will no longer trigger seat-belt reminders. Airbags could deploy at different speeds when children are present in the car, reducing the risk of impact injuries. Drivers could receive reminders that infants or children are still inside vehicles, since radar detects lifeforms with higher accuracy and reliability than any other sensor technology out there.

A radar sensor can also accurately detect when a driver becomes drowsy by estimating their heartbeat and breathing rate with reliable accuracy as shown in **Figure 7**. One single sensor has the ability to monitor vital signs for all occupants inside a car – information that the vehicle can then use to identify potential medical abnormalities and potentially alert occupants, especially driver alert status. Once warned, drivers could take appropriate actions such as taking a break or pulling over in the event of a medical issue.

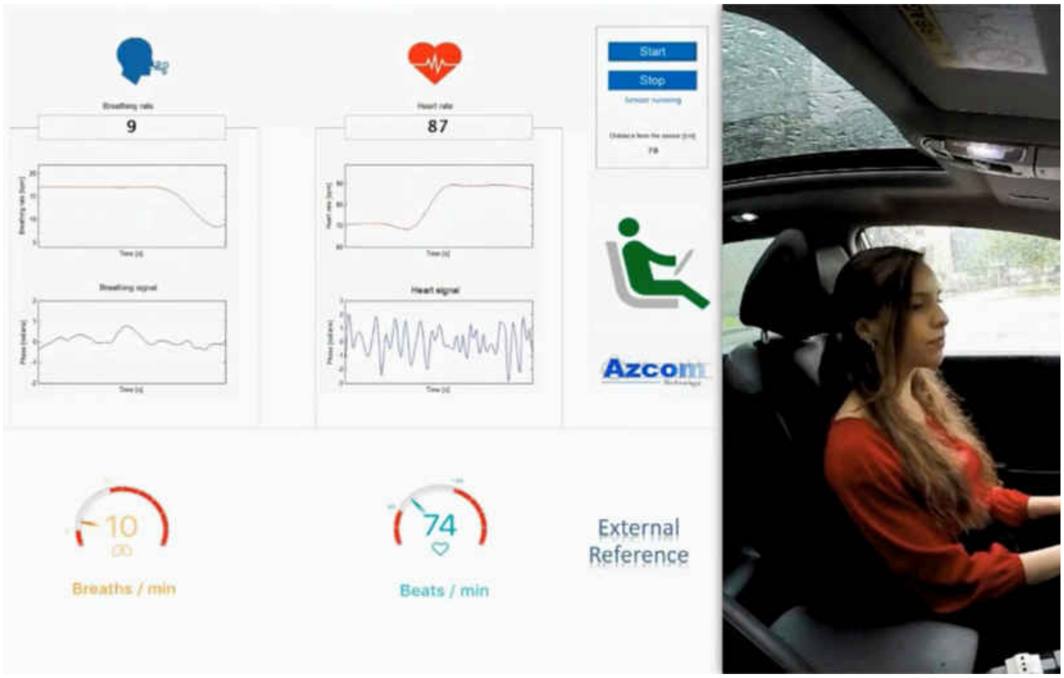

Figure 7. *Demonstration of heart rate and breathing estimation using 60-GHz mmWave radar. (Source: Azcom Technologies).*

Also, today drivers have to take their eyes off the road in order to adjust various comfort and convenience functions through button switches or knobs. A radar sensor can detect gestures such as a swipe of a hand or twirl of finger. A hand swipe from right to left could indicate that the user wishes to change radio stations, while a twirl of a finger in an anti-clockwise direction could mean decrease the volume or zoom out on a navigation map, greatly simplifying the driving experience. Passengers in the second row could also browse movie selections on headrest screens with a swipe of a hand, rather than having to extend their hands toward the screen to touch a knob.

Thus, radar sensors are redefining the interior sensing mechanism inside vehicles by assisting drivers and passengers and also providing comfort functions.

Conclusion

In conclusion, adoption of mmWave radar sensors by car manufacturers is continuously increasing due to the benefits it brings for various applications – long range, mid range , short range and ultra-short range and in-cabin applications. Primarily, radar being agnostic to weather and environmental conditions, makes it extremely important to increase reliability and safety of the car. As the number of sensors increases with autotomy, performance and cost are the main key care abouts. With high level of integration with antenna, radar transceiver, digital signal processor, microcontroller and interface peripherals all onto one chip, in addition to performance, automakers and Tier-1 suppliers are able to reduce overall system costs. In addition, multimodal functionality allows extending these existing sensors from ADAS, with high performance long range to emerging applications such as parking with short range and higher resolution. Developers also have a wide and scalable range of solutions to choose from the TI portfolio based on their design needs. TI's whole product offering, hardware, software and reference designs, for each of these applications makes adoption easier and enables a faster time to market.

Learn more about TI radar sensors at: **https://www.ti.com/sensors/mmwaveradar/automotive/overview.html**

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